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Summary of the doctoral dissertation entitled:

„Evaluation of the occurence of rare earth elements in soils and waste and potential for their recovery through phytoextraction"

Keywords: rare earth elements, phytoextraction, contaminated soil, phytoremediation technique, chelate assisted phytoextraction

Rare earth elements (REE) are a group of 17 elements, which include 15 lanthanides and 2 scandiums. Due to the wide range of metal use in areas such as modern technologies, industry, medicine and agriculture, REE have been classified by the European Union as critical raw materials (CRM).

Currently, traditional mining methods are used to extract REE. As a result, there is a growing interest in finding natural methods that allow for the recovery of REE from the environment. Such methods include phytoremediation techniques. This paper focuses on one of the phytoremediation techniques – phytoextraction. This technique uses plants to recover metals from the substrate.

The research hypothesis assumed that an alternative source of REE in the environment may be landfills of various types of industrial waste. In turn, the use of appropriate plant species and additives facilitating the uptake of REE from the substrate may lead to the development of optimal methods of phytoextraction of these elements from various substrates. The main objective of the study was to determine the efficiency of phytoextraction of rare earth elements (REE) from soil and industrial waste by selected plant species

The research was divided into three stages. In the first stage, REE contents in waste and representative soils were determined. Then, in the first greenhouse experiment, differences in REE accumulation between plant species were studied: common yarrow (*Achillea millefolium* L.), false mayweed (*Tripleurospermum maritimum* (L.) W.D.J. Koch), tall fescue (*Festuca arundinacea* Schreb.), marigold (*Tagetes* sp.), maize (*Zea mays*), white mustard (*Sinapsis alba*), red clover (*Trifolium pratense* L.) and autumn fern (*Dryopteris erythrosora* (D.C. Eaton)

Kuntze) were grown on soil and substrates composed with fly ash and flotation waste. In the second greenhouse experiment, the main attention was paid to determining the efficiency of REE uptake and accumulation by: *A. millefolium*, *T. pratense* and *D. erythrosora* after application of chelates: CA, EGTA and EDTA to the growing media. In this experiment, two substrates were used, the first containing soil enriched with lanthanide chlorides and the second containing fly ash.

It was demonstrated that higher REE contents were present in fly ash waste and soils compared to sewage sludge and slags. In greenhouse experiments, the obtained results provided information that plants accumulate higher REE contents in their underground parts compared to the above-ground parts. It was shown that the type of substrate affects the uptake and accumulation of REE by plants. Additionally, plant growth and accumulation of elements were slightly more efficient in case of substrates containing soil than from industrial waste based growing media. Plants accumulated quite low REE amounts. The addition of chelates did not significantly enhance metal accumulation and the effects was specific to the plant species and the substrate used. The most effective plant in the entire experiment was *D. erythrosora*, which was characterized by greater bioconcentration (BCF) and translocation factors (TF) than the other plants. In general, the calculated BCF and TF indices were lower than 1 for most of the tested plant species. The highest BCF index = 0,47 was obtained in the first greenhouse experiment for *Zea mays* (substrate 1). But the highest TF index = 5.42 was obtained in the second experiment for *D. erythrosora* (La, 10 mM CA, substrate2).

The conducted studies provided a lot of information, not existing before, on the uptake and accumulation of rare earth elements by plants, as dependent on individual plant species and types of substrates. The data obtained is is a valuable information for further research. Further work should focus on selecting the optimal combinations of chelates and their doses for individual plants. We should also look for wastes with higher REE contents and methods of producing substrates that provide more favorable conditions for REE uptake by plants, e.g. with lower pH.

mgr Dominika Gmur